METHOD, APPARATUS AND SYSTEM FOR SUBSTANTIALLY REDUCING OR ELIMINATING THE PLUGGING OF DOWNHOLE SAND CONTROL SCREENS

BACKGROUND

[0001] The present invention relates generally to methods and apparatuses for reducing the plugging of downhole sand control screens and more particularly to the use of shale shaker screens manufactured from the same diffusion bonded wire laminates as the sand control screens.

[0002] The use of wire mesh sand control screens, including expandable screens, offers operators a solution to sand control problems and is a common practice. However, the performance of these sand control screens can be impaired if particles become trapped in the mesh, reducing the permeability of the screen and therefore well productivity. Common sources of these plugging particles are the drilling muds or drill-in fluids (collectively, drilling fluids) used in the production interval. When the screen first enters the wellbore, the wellbore fluid enters the screen pores and any particles that are in the fluid enter the mesh and can reduce the screen permeability and subsequent production rates.

[0003] A number of different solutions have been proposed to substantially reduce or eliminate the plugging of downhole sand control screens. One such solution involves employing shale shakers to remove the particles from the drilling fluid. Shale shakers are large surface devices, typically located on the drilling rig, which filter undesired particles from drilling fluids. Shale shakers operate by passing the particle bearing fluid through a vibrating screen or series of screens, which are typically arranged in a tiered or flat disposition with respect to each other. The screens catch and remove solids from the drilling fluid as the fluid is passed through the screens.

[0004] In some shale shakers, a fine screen cloth is used with the vibrating screen. The screen may have two or more overlying layers of screen cloth. The frame of the vibrating screen is

suspended or mounted upon a support and is caused to vibrate by a vibrating mechanism, *e.g.*, an unbalanced weight on a rotating shaft connected to the frame. Each screen may be vibrated by vibratory equipment to create a flow of trapped solids toward an end of the screen on a top surface of the screen for removal and disposal of solids. The fineness or coarseness of the mesh of a screen may vary depending upon fluid flow rate and the size of the solids to be removed.

[0005] Typically, shale shaker screens comprise three layers with each layer varying in degree of fineness; although a different number of layers may be employed. The coarsest layer is disposed on the bottom and the finest layer is disposed on the top. The layers are typically bonded together by either epoxy bonding or thermoplastic bonding.

[0006] In the first bonding method, the layers are stacked one on top of the other and placed over a rigid stainless steel support frame, which has a generally rectangular perimeter and grid-shaped interior. An epoxy material is then applied over the layers in the regions where the layers overlap the frame. The layers are then heated and cured to form a unitary structure. A drawback of this design is that the stainless steel frame covers approximately 20-25% of the screen. This is known as blanking and decreases the rate at which the drilling fluid can pass through the screen, which in turn decreases the efficiency at which contaminants can be removed from the drilling fluid. A further drawback of this design is that the layers are only bonded to one another over approximately 20-25% of their surface area. Therefore, the layers are free to move relative to one another over the active portion of their surface area, *i.e.*, the portion over which the contaminated drilling fluid passes. The movement of the layers relative to one another, which is prompted by the vibration of the screens as well as the impact of the contaminated drilling fluid passing through the screen, can weaken the layers and ultimately cause them to fail.

[0007] In the second method, the three layers are placed over a thermoplastic bonding substrate, which like the stainless steel frame used in the epoxy bonding technique, has a generally rectangular perimeter and grid-shaped interior. The four layers are heated and cured. The screen layers bond to one another around the perimeter of the bonding substrate and in the regions of the grid. This screen has the same drawback as the epoxy-bonded screen in that approximately 20-25% of the screen is unusable because the regions of the grid block the flow of the drilling fluid. This type of screen also has the drawback of not having a particularly long life cycle because the layers are free to move relative to one another in the regions where they are not bonded together, which is approximately 75-80% of the screen's surface. Furthermore, the thermoplastic-bonded screens are not rigid, and therefore are even more susceptible to damage than the epoxy-bonded screens.

[0008] A further drawback of conventional shale shaker screens is that they do not have fixed pore sizes. That is because the wire mesh making up each layer is not rigid nor is each layer rigidly attached to each adjacent layer in the stack. A consequence of this construction is that certain large particles that should theoretically not pass through the screen do so any way despite the fact that they have effective diameters larger than the average pore size of the screen. The force of such particles passing through the screen cause the individual wires making up the screen to spread apart, which in turn enlarges the pores and allows other particles to pass through the screen. This has the detrimental effect of not removing substantially all of the particulate matter from the drilling fluid, which in turn increases the likelihood that the downhole sand control screen will plug up prematurely when it is placed in the well containing the contaminated drilling fluid.

[0009] Finally, whereas downhole sand control screens are typically custom-made for a particular application, conventional shale shaker screens used in such applications only come in a limited number of standard sizes. As a consequence, one standard size shale shaker screen will be used in many different applications to filter many different types and sizes of particulate matter. A drawback of such systems is that one size does not always fit all. In other words, while one standard size screen may work well in removing substantially all of the particulate matter emanating from one particular formation of a certain type, it may not work well in removing substantially all of the particulate matter emanating from another formation of the same or different type. Indeed, it is for this very reason that the sand control screens themselves are often custom-made for the particular application.

SUMMARY

[0010] The present invention provides an improved shale shaker screen which meets the needs described above and overcome the deficiencies of the prior art.

[0011] In one embodiment, the present invention is directed to a method of removing particulate matter from a drilling fluid such as a drilling mud or drill-in fluid by passing the drilling fluid through a shale shaker screen which is formed of a plurality of layers of screens that have been diffusion-bonded together. More specifically, the shale shaker screen is formed of the same screen material that is used to form the downhole sand control screen being used for the formation of interest. Preferably, it is custom formed for the particular formation of interest. In one aspect of the present invention, the drilling fluid is passed through the shale shaker screen before it is pumped downhole for the first time. This removes any particulate matter that may be present in the fluid from a previous job. In another aspect of the present invention, the drilling fluid is again passed through the shale shaker screen upon circulation of the fluid through the wellbore during drilling. In yet another aspect of the present invention, the drilling fluid is again circulated through the improved shale shaker screen according to the present invention after the drilling operation is finished, but before the sand control screen is placed into the well containing the drilling fluid. Indeed, in all of the embodiments, the sand control screen is placed into the well only after the drilling fluid has been circulated through the shale shaker screen in accordance with the present invention.

[0012] In a preferred embodiment of the present invention, the shale shaker screen comprises three layers of screens of different pore size that are stacked one on top of the other. The layer having the smallest pore size is placed at the top of the stack and the layer having the largest pore size is placed at the bottom of the stack. The top screen layer has a pore size that is

approximately 75 microns, the middle screen layer has a pore size of approximately 150 microns, and the bottom screen layer has a pore size of approximately 850 microns. Each screen layer is preferably formed of a stainless steel such as 316L, Alloy 20 or Hastolloy. At least one of the screen layers also preferably has an aspect ratio of approximately 2:1.

[0013] In another embodiment of the present invention, a system for removing particulate matter from a drilling fluid is provided. The system includes a pump that pumps the drilling fluid into the wellbore and recirculates the drilling fluid back to the surface and a shale shaker that filters out the particulate matter from the drilling fluid by passing the drilling fluid through a vibrating screen formed in accordance with the present invention.

[0014] Other and further objects, features and advantages of the present invention will be readily apparent to those skilled in the art upon a reading of the description of preferred embodiments which follows.

Brief Description of the Drawings

[0015] The present invention is better understood by reading the following description of non-limitative embodiments with reference to the attached drawings wherein like parts of each of the several figures are identified by the same referenced characters, and which are briefly described as follows:

[0016] Figure 1 is a schematic diagram of a system for removing particulate matter from a drilling fluid in accordance with one embodiment of the present invention.

[0017] Figure 2 is a schematic diagram of a system for removing particulate matter from a drilling fluid in accordance with another embodiment of the present invention.

[0018] Figure 3 is a flow diagram illustrating the steps in forming a shale shaker screen in accordance with the present invention.

[0019] Figure 4 is a schematic diagram illustrating the structure of a preferred shale shaker screen in accordance with the present invention.

[0020] It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, as the invention may admit to other equally effective embodiments.

Detailed Description Of The Invention

[0021] The details of the present invention will now be discussed with reference to the figures. Figure 1 illustrates one embodiment of a system for removing particulate matter from a drilling fluid such as a drilling mud or drill-in fluid shown generally by reference numeral 10. In this embodiment, the system 10 removes particulate matter from the drilling fluid before it is pumped downhole and continues to remove particulate matter from the drilling fluid as the drilling fluid is re-circulated through a drill assembly 12 either during or after drilling.

[0022] The drill assembly 12 includes a drill pipe 14 connected to a drill bit 16 at an end of the drill pipe 14. The drill pipe 14 is formed of a steel pipe and the drill bit 16 may be either a rotary drill bit or a hydraulically operated drill bit such as a Dynadrill or other equivalent device. The drill assembly 12 also includes a casing string 18, which is shown in Figure 1 as partially installed in a wellbore 20. The casing string 18 is also preferably formed of a steel pipe and is cemented to the wall of the wellbore 20. An annulus 22 is formed between the drill pipe 14 and casing string 18. As those of ordinary skill in the art will recognize, the drill assembly 12 can take many forms. Indeed, only one such embodiment is illustrated herein as the drill assembly 12 by itself does not form part of the present invention. Furthermore, as those or ordinary skill will recognize, the present invention can also be used in open hole applications.

[0023] The system 10 includes a drilling fluid storage tank 30, a shale shaker 32 and a positive displacement pump 34. The drilling fluid is delivered from the storage tank 30 to the shale shaker 32 via conduit 36, which is preferably a heavy-gauge hose. A control valve 38 coupled to the conduit 36 meters the flow of the drilling fluid into the shale shaker 32. The control valve 38 may be a butterfly valve, a ball valve or other known equivalent device.

Although not illustrated, a pump may be employed to deliver the drilling fluid from the storage tank 30 to the shale shaker 32.

[0024] The drilling fluid is directed onto a vibrating screen 40 which is part of the shale shaker 32. Indeed, the present invention is directed to the structure of the screen 40. In its preferred form, the screen 40 is custom-made and is formed from the same multi-layer woven mesh filter media used in making the sand control screens that will be placed in the wellbore 20 after drilling. The screen 40 is preferably formed by diffusion bonding using a commercially available filter media such as Poroplate® from Purolator Products Company, 8439 Triad Drive, Greensboro, N.C. It preferably comprises several layers of differing mesh size, *e.g.,* three such layers. Preferably, the screen having the smallest diameter pore size is disposed on the top and that having the largest diameter is disposed on the bottom. As those of ordinary skill in the art will recognize, screens having more than three layers or less than three layers may be employed. Preferably, two to five layers will be employed but a different number of layers outside of that range may also be employed. Additional details concerning the screen 40 will be provided below.

[0025] Once the drilling fluid has passed through the screen 40 and has had particulate matter removed from it, it is directed to the positive displacement pump 34. The drilling fluid is delivered from the shale shaker 32 to the positive displacement pump 34 via the conduit 42, which is preferably a heavy-gauge hose. A control valve 44 coupled to the conduit 42 meters the flow of the drilling fluid into the positive displacement pump 34. The control valve 44 may be a butterfly valve, a ball valve or other known equivalent device. Although not illustrated, a pump may be employed to deliver the drilling fluid from the shale shaker 32 to the positive displacement pump 34.

[0026] Although only one positive displacement pump 34 is shown, multiple such pumps may be employed to circulate the drilling fluid through the drill assembly 12. One example of such a pump is a 6 inch Halliburton HT-2000™ pump. The positive displacement pump 34 in turn pumps the drilling fluid through the drill pipe 14 via conduit 46, which is preferably a heavy-gauge hose. A control valve 48 coupled to the conduit 46 meters the flow of the drilling fluid into the drill pipe 14. The control valve 48 may be a butterfly valve, a ball valve or other known equivalent device.

[0027] The drill pipe 14 in turn delivers the drilling fluid to the drill bit 16. The drilling fluid keeps the drill bit 16 lubricated and operates to remove drill cuttings from the wellbore 20 in the region where the drill bit 16 is operating. After the drilling fluid passes over the drill bit 16, it is returned to the surface carrying the drill cuttings and other particulate matter present in the wellbore 20 from the drilling operation. The drilling fluid is pumped back up to the surface through the annulus 22 between the drill pipe 14 and the casing string 18.

[0028] The drilling fluid is returned to the shale shaker 32 for further filtering by the screen 40 via a conduit 50, which is preferably a heavy-gauge hose. A control valve 52 coupled to the conduit 50 meters the flow of the drilling fluid back to the shale shaker 32. This flow of the drilling fluid through the system 10 and drill assembly 12 repeats continuously during the drilling operation. The drilling fluid may also be circulated through the system 10, and thus the shale shaker screen 40, after the drilling operation has finished. It is important, however, that the particulate matter be removed from the drilling fluid before the sand control screen is placed into the wellbore 20 filled with the drilling fluid.

[0029] In another embodiment of the present invention the drilling fluid is not pre-filtered through the shale shaker 32 before being pumped downhole. Rather, the drilling fluid is delivered

directly from the storage tank 30 to the positive displacement pump 34. This embodiment is illustrated in Figure 2. In comparing Figures 1 and 2, the last two digits of the reference numerals in Figure 2 indicate identity with like components in Figure 1. For example, reference numerals 16 and 116 both refer to the drill bit, which is an identical component in both figures. The only difference in the two embodiments from a configuration stand point relates to how the conduit 36 is connected. In Figure 1, it connects the drilling fluid storage tank 30 to the shale shaker 32. In Figure 2, like conduit 136 connects the drilling fluid storage tank 130 directly to the positive displacement pump 134. By connecting the conduit 36 to the shale shaker 32, the system 10 is capable of pre-filtering the drilling fluid. This is desirable especially where the drilling fluid is left over from a prior job. Where the drilling fluid has not previously been used on a job, it would not be necessary to prefilter it in which case the embodiment shown in Figure 2 would be sufficient.

[0030] The steps in constructing the screen 40, 140 in accordance with the present invention will now be described with reference to Figure 3. Reference numeral 400 refers generally to the process of constructing the screen 40, 140 in accordance with the present invention. First, the process 400 is initiated 410. In the first step 420, the optimum number of layers and mesh size of each layer is selected based upon data corresponding to the characteristics of the subterranean formation of interest. Each layer is then constructed into sheets in accordance with the selected parameters using known manufacturing techniques to make wire mesh screens. As pointed out above, in accordance with the present invention, each screen layer is also used to construct the downhole sand control screen.

[0031] In the next step 430, the plurality of layers of screens used to construct the screen are cut to size. In most embodiments, three layers of screen will likely be employed. However, as

indicated above any number of screens can be utilized depending upon the nature of the subterranean formation.

[0032] In step 435, the layers of screens are arranged one on top of the other. Preferably, the screen having the smallest pore size is placed on the top and the screen having the largest pore diameter is placed on the bottom. Where more than three layers of screens are utilized, the layers are preferably arranged top to bottom in increasing pore size. In one example, three layers are employed with the top layer having a pore size of approximately 75 microns, the middle layer having a pore size of approximately 150 microns and the bottom layer having a pore size of approximately 850 microns.

[0033] In the next step 440, the stacked layers of screens are placed in a press, *e.g.,* a vice, which applies a compressive force to the layers forcing them into face to face contact with one another. The pressure applied to the layers is preferably approximately 100 – 500 lbs. The stacked layers of screens are then placed in a heating chamber in step 450. The heating chamber is hermetically sealed and then filled with an inert gas, *e.g.,* dry hydrogen, which frees the screens of contaminates in step 460. Next, in step 470, the stack of screens is heated to a temperature of approximately 2200 °F. The stack of screens is heated at that temperature for approximately 24 hours. They are then removed from the heating chamber and allow to cool in step 480. The process is then complete (step 490) and the screen 40, 140 is ready for installation in the shale shaker 32, 132. This entire process takes approximately 3 days and results in a screen that is diffusion bonded which, as those of ordinary skill in the art will appreciate, in effect is welded at all points where the layers of screens come into contact with one another. The resulting screen has fixed pores, no blanking and is very strong in comparison to conventional shale shaker screens.

[0034] Figure 4 illustrates how a three layer screen of varying pore size is preferably arranged prior to annealing and also illustrates the final diffusion-bonded screen 40, 140. In one alternate embodiment, a fourth solid metal layer may be employed as the bottom layer for additional support. This layer would have a large cut out in the middle over which the active region of the other layers would be disposed. In other words, the fourth layer (in this example) would in effect be a support frame which supports the other layers of the screen around their perimeter. Unlike the grids in the prior art devices, this support frame would not block the flow of the drilling fluid because no part of the frame would extend into the active region of the screen.

[0035] Furthermore, as those of ordinary skill in the art will appreciate, the screen 40 is preferably sized so as to fit any commercial model of shale shaker. Also, each layer is preferably constructed of a stainless steel wire mesh. Preferably, at least one of the layers of the screens is formed of a high aspect ratio rectangular mesh, *e.g.,* approximately 2:1. An example of such a mesh is a TechMesh™ wire cloth manufactured by Baroid.

[0036] Therefore, the present invention is well adapted to carry out the objects and attain the ends and advantages mentioned as well as those that are inherent therein. While numerous changes may be made by those skilled in the art, such changes are encompassed within the spirit of this invention as defined by the appended claims.

[0037] What is claimed is: